

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0302 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: LH2 OUTBOARD 8" FILL/DRAIN VALVE UNITED SPACE ALLIANCE - NSLD	MC284-0397-0031 74328000-159

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LH2 OUTBOARD FILL VALVE, 8 INCH. PNEUMATICALLY OPERATED, INCLUDES A RELIEF VALVE.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY FAIRCHILD CONTROLS BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PV11

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE OUTBOARD VALVE PREVENTS OVERBOARD LOSS OF PROPELLANT DUE TO LEAKAGE FROM THE LH2 INBOARD FILL & DRAIN VALVE (PV12) AND/OR THE LH2 TOPPING VALVE (PV13). THE VALVE IS MOUNTED ON THE FILL AND DRAIN DISCONNECT AND REMAINS OPEN FROM START OF LOADING OPERATIONS TO COMPLETION OF TSM DRAIN (APPROXIMATELY T - 48 SEC). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION. POST MECO, THE VALVES ARE OPENED BY SOFTWARE COMMAND TO DUMP LH2. THE OUTBOARD VALVE IS SUBSEQUENTLY OPENED BY SOFTWARE TO VENT LH2 RESIDUALS DURING THE FIRST VACUUM INERT. THE OUTBOARD VALVE IS ADDITIONALLY OPENED MANUALLY DURING THE SECOND VACUUM INERT. (EFFECTIVE FOR OI-29 AND SUBS, THE FILL/DRAIN VALVES WILL NO LONGER BE USED FOR VACUUM INERTS. VACUUM INERT WILL BE ACCOMPLISHED VIA THE RTLS DUMP VALVES, PV17 & PV18). THE OUTBOARD VALVE IS CLOSED PRIOR TO ENTRY FOR MANIFOLD REPRESSURIZATION. INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE ALSO INCORPORATES A RELIEF VALVE, RELIEVING INTO THE FILL LINE.

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FAILS TO OPEN FOR LH2 DUMP, DETANKING

MISSION PHASE:

PL	PRE-LAUNCH
LO	LIFT-OFF
LS	LANDING/SAFING

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:

PIECE PART STRUCTURAL FAILURE, BINDING, ACTUATOR LEAKAGE, ANTI-SLAM VALVE LEAKAGE, ACTUATOR FILTER CLOGGING

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**REDUNDANCY SCREEN**

A) PASS
 B) PASS
 C) PASS

PASS/FAIL RATIONALE:

A)

B)

PASSES B SCREEN BASED ON FUNCTIONING POSITION INDICATOR. ERRONEOUS INDICATION (FAILURE OF POSITION INDICATOR TO PROPERLY DISPLAY VALVE POSITION) IS COVERED BY CIL 03-1-0302-03.

C)

- FAILURE EFFECTS -**(A) SUBSYSTEM:**

RESULTS IN INABILITY TO DETANK. DURING THIS TIME THE HIGH POINT BLEED VALVE (PV22) AND THE ET VENT VALVE WILL PROVIDE RELIEF CAPABILITY. ALSO RESULTS IN LOSS OF

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CAPABILITY TO DUMP/INERT THROUGH THE FILL & DRAIN SYSTEM. LH2 PRESSURE RELIEF (POST MECO) IS THROUGH THE MANIFOLD RELIEF SYSTEM.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT IN FLIGHT. LAUNCH SCRUB FOR FAILURE PRIOR TO TANKING.

(D) CREW, VEHICLE, AND ELEMENT(S):

NO EFFECT ON NOMINAL, TAL, AOA, AND ATO MISSIONS. FOR RTLS ABORTS, THIS FAILURE WOULD RESULT IN APPROXIMATELY 40 POUNDS OF RESIDUAL LH2 ON BOARD AT LANDING. THE FEEDLINE RELIEF SYSTEM DOES NOT HAVE THE CAPACITY TO COMPLETELY DISSIPATE RESIDUAL LH2 PRIOR TO TOUCHDOWN. HAZARD DURING POST LANDING OPS DUE TO EXTENDED LH2 BURNOFF TIME THROUGH THE FLAME ARRESTOR (FL1) (RESULTS IN HIGH HEAT FLUX AT THE VERTICAL STABILIZER).

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) OUTBOARD FILL & DRAIN VALVE (PV11) FAILS TO OPEN.
- 2) EITHER RTLS DUMP VALVE (PV17, 18) FAILS TO OPEN. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO FOR 110 SECONDS, BUT CAN BE OPENED BY THE CREW IF MANIFOLD PRESSURE APPROACHES RELIEF PRESSURES. EFFECTIVE FOR OI-29 AND SUBS THE RTLS DUMP VALVES WILL BE USED FOR LH2 VACUUM INERTING.
- 3) MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - DETANK.

- 1) OUTBOARD FILL & DRAIN (PV11) FAILS TO OPEN.
- 2) ET LH2 RELIEF VALVE FAILS TO RELIEVE.
- 3) HIGH POINT BLEED VALVE (PV22) FAILS TO OPEN/REMAIN OPEN.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. RTLS DUMP VALVES (PV17,18) AND LH2 MANIFOLD RELIEF ISOLATION VALVE (PV8) CAN BE OPENED BY GROUND ACTION, BUT THIS WOULD DUMP LH2 ONTO THE PAD SURFACE. POSSIBLE LOSS OF CREW/VEHICLE.

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-DISPOSITION RATIONALE-

(A) DESIGN:

DESIGNED FOR FACTORS OF SAFETY OF 1.3 PROOF AND 1.5 BURST FOR THE VALVE BODY, 1.5 PROOF AND 2.0 BURST FOR THE ACTUATOR. STRUCTURAL FAILURE IS AVOIDED BY MANUFACTURING THE POWER TRAIN OF INCONEL 718 AND COPPER-BERYLLIUM COMPONENTS. BINDING IS GUARDED AGAINST BY THE USE OF ROLLER BEARINGS THROUGHOUT.

THE ACTUATOR DRIVES THE VALVE VIA A LINEAR RACK AND PINION GEAR (BOTH OF COPPER-BERYLLIUM), AND THE RACK IS POWERED BY A HELIUM-DRIVEN DOUBLE-ACTING PISTON. LEAKAGE ACROSS THE PISTON IS PRECLUDED BY FOUR SEALS (TWO AT EACH END OF THE PISTON) OF TEFLON JACKETED, METALLIC "V" TYPE (THE METALLIC "V" SPRING IS OF 301 CRES). THIS SAME TYPE OF SEAL IS USED TO PREVENT EXTERNAL LEAKAGE AT ALL ACTUATOR JOINTS.

THE ANTI-SLAM VALVES USE A286 CRES POPPETS SPRING LOADED TO KEL-F SEATS. WITH THE ANTI-SLAM PORT VENTED, ACTUATION PRESSURE ASSISTS THE SPRING IN SEALING THE POPPET TO THE SEAT. BINDING IS CONSIDERED UNLIKELY BECAUSE ALL SLIDING SURFACES ARE COATED WITH A DRY FILM LUBRICANT WHICH HAS HAD EXTENSIVE UTILIZATION WITHOUT PROBLEMS.

THE VALVE IS DESIGNED FOR 5000 LIFE CYCLES AND WAS TESTED THROUGH 5,256 CYCLES (OVER 100 MISSIONS) AT BOTH CRYOGENIC AND AMBIENT TEMPERATURE CONDITIONS AND AT BOTH NORMAL AND ACCELERATED (SLAM) CYCLE TIMES. THE VALVE, DURING THIS LIFE CYCLE TESTING, NEVER FAILED TO OPEN. FILTERS ARE PROVIDED ON ALL PNEUMATIC PORTS TO PREVENT CONTAMINATION.

(B) TEST:

ATP

ANTI-SLAM VALVES (BEFORE ASSEMBLY INTO THE ACTUATOR) - EXAMINATION OF PRODUCT; AMBIENT PROOF (1275 PSIG); AMBIENT AND CRYO FLOW; AMBIENT AND CRYO CRACKING PRESSURE; POST TEST EXAMINATION.

ACTUATOR (BEFORE ASSEMBLY ONTO THE FILL AND DRAIN VALVE) - EXAMINATION OF PRODUCT; POSITION INDICATION; AMBIENT PROOF (1275); ELECTRICAL CHARACTERISTICS; AMBIENT EXTERNAL LEAKAGE.

RELIEF VALVE ASSEMBLY (BEFORE INSTALLATION INTO THE FILL AND DRAIN VALVE) - EXAMINATION OF THE PRODUCT; AMBIENT PROOF (340 PSIG); AMBIENT AND CRYO CRACK/RESEAT (15-50 PSID) AND INTERNAL LEAKAGE; POST TEST EXAMINATION.

FILL AND DRAIN VALVE ASSEMBLY -

EXAMINATION OF PRODUCT

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ELECTRICAL BONDING

AMBIENT AND CRYO PROOF WITH VALVE OPEN AND CLOSED - 143 PSIG

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (110 PSIG)

CRYO EXTERNAL LEAKAGE OF ACTUATOR (740 PSIG)

AMBIENT AND CRYO RESPONSE TIME (NORMAL AT 400 AND 740 PSIG ACTUATOR PRESSURE, AND SLAM AT 740 PSIG)

AMBIENT AND CRYO ACTUATOR LEAKAGE FROM PORT TO PORT

AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 110 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 110 PSID)

AMBIENT AND CRYO RELIEF VALVE CRACK AND RESEAT (15 TO 50 PSID)

POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-400 DEG F) (AXIAL, SHEAR, TORSION, BENDING) WITH THE VALVE IN TENSION, PERFORM VALVE RESPONSE TIME (NOMINAL AND SLAM) ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND, EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 AMBIENT TEMPERATURE CYCLES WITH 5 PSIG INTERNAL PRESSURE (525 NORMAL CYCLES AND 1875 SLAM CYCLES)

100 AMBIENT CYCLES (50 NORMAL AND 50 SLAM CYCLES) WITH VALVE INLET VENTED TO ATMOSPHERE AND VALVE OUTLET CONNECTED TO A 4 CUBIC FOOT VOLUME PRESSURIZED TO 110 PSIG WITH GN2

2400 CRYO TEMPERATURE (-400 DEG F) CYCLES WITH 50 - 60 PSIG INTERNAL PRESSURE (1775 NORMAL CYCLES AND 625 SLAM CYCLES)

100 NORMAL CRYO CYCLES WITH THE VALVE INLET VENTED TO ATMOSPHERE AND THE OUTLET PRESSURIZED TO 110 PSIG.

FOR THE FOREGOING LIFE TEST, PRIOR TO AND EVERY 100 CYCLES THEREAFTER, ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, AND VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET) TESTS WERE PERFORMED.

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RELIEF VALVE LIFE CYCLING:

2500 CYCLES AT CRYO (-400 DEG F) TEMP, 2500 CYCLES AT AMBIENT.

FOLLOWING EACH 500 CYCLES PERFORM FILL AND DRAIN VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), AND CRACK/RESEAT TESTS. POST CYCLE EXAMINATION.

VIBRATION:

PRE-VIBRATION TESTS - VALVE RESPONSE TIME (NORMAL AND SLAM), ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR).

TRANSIENT SINUSOIDAL VIBRATION -
(AT 110 PSIG AND -250 DEG F) IN EACH AXIS

RANDOM VIBRATION TESTS -
13.3 HRS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 110 PSIG; THE OTHER HALF AT 5 PSIG. ONCE EACH HOUR, CLOSING PRESSURE IS REMOVED FROM THE ACTUATOR. ALSO BOTH CLOSING AND OPENING PRESSURES ARE APPLIED CONCURRENTLY TO THE ACTUATOR. IN BOTH CASES THE VALVE REMAINS CLOSED.

DESIGN SHOCK: 18 SHOCKS OF 15G EACH - THREE IN EACH DIRECTION ALONG EACH OF THREE AXES, ALL WITH VALVE OPEN AND ACTUATOR VENTED

DESIGN SHOCK POST TEST:
AMBIENT - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. CRYO - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. ELECTRICAL CHARACTERISTICS; POSITION INDICATION.

BURST: 165 PSIG VALVE OPEN 165 PSIG ON OUTLET OF CLOSED VALVE, 1700 PSIG ACTUATOR

GROUND TURNAROUND TEST
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION
RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. BODY HOUSING FORGING IS ULTRASONICALLY AND PENETRANT INSPECTED.

CONTAMINATION CONTROL
PARTS ARE VERIFIED CLEAN TO LEVEL 400. THE ACTUATOR IS CLEANED TO 400A.

ASSEMBLY/INSTALLATION

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ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. LOG OF CLEAN ROOM AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. VISUAL (3X TO 7X) AND DIMENSIONAL INSPECTION OF VALVE BODY AND COMPONENTS ARE VERIFIED DURING ASSEMBLY. THREADED FASTENER TORQUES ARE VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT AND DRY FILM LUBE APPLICATION ARE VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION

VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO DYE PENETRANT INSPECTION. REQUIREMENTS FOR DETAIL PARTS PENETRANT INSPECTION ARE BASED UPON CONFIGURATION, MATERIAL, AND MANUFACTURING PROCESSES.

TESTING

ACCEPTANCE TEST VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

MINOR LEAKS HAVE OCCURRED AT KSC, MPTA, AND SUPPLIER FROM THE ACTUATOR CYLINDER BODY FLANGE AND COVER PLATE AREA (CAR AB8134, AB3674, AC7678, AC7920, AC7738, AD0528). CORRECTIVE ACTION INVOLVED SEAL REPLACEMENT, SEALING SURFACE POLISHING, AND CAUTIONING OF PERSONNEL.

BERYLLIUM-COPPER METALLIC CHIPS WERE DETECTED ON THE MAIN SHAFT IN THE QUALIFICATION TEST UNIT (CAR AC4400). CHIPS WERE GENERATED BY FAULTY HEAT TREATED RING RETAINERS (WHICH ACT AS THRUST BEARERS FOR THE VALVE DRIVE SHAFT). IT WAS ALSO FOUND THAT DRY FILM LUBRICANT HAD NOT BEEN APPLIED TO THE SHAFT BEARING INNER RACES. ALL FAULTY RETAINERS WERE REPLACED WITH CORRECTLY HEAT TREATED RETAINERS. SHAFT BEARING INNER RACES WERE PROPERLY LUBRICATED.

FATIGUE CRACKS IN ACTUATOR END CAPS (CAR AD1230) AND LOOSE END CAP BOLTS (CAR AC7678) WERE DETECTED DURING INCIPIENT FAILURE INVESTIGATION. THE PROBLEM WAS CORRECTED BY A REDESIGN OF THE END CAPS. ALSO, THE ATTACHMENT BOLTS WERE CHANGED FROM NAS1101E4-12 TO RD111-4008-0404 WHICH INCREASED THE BOLT HEAD SIZE. A REQUIREMENT TO RETORQUE THE ATTACHMENT BOLTS 4 HOURS AFTER APPLICATION OF INITIAL TORQUE WAS INSTITUTED.

MPTA VALVE FAILED TO CYCLE TO CLOSE POSITION DUE TO A PREVIOUS SLAM OPERATION (FAILURE TO APPLY SNUBBING PRESSURE), REFERENCE CAR AB5938. THE VALVE WAS REDESIGNED TO ADD AN ANTI-SLAM CAPABILITY WHICH DIRECTS HELIUM ACTUATION PRESSURE SIMULTANEOUSLY FROM THE ACTUATION PORT TO THE OPPOSITE ANTI-SLAM PORT. THIS PROVIDES SNUBBING PRESSURE AND PRECLUDES SLAMMING.

THE DEVELOPMENT VALVE EXPERIENCED A NEEDLE BEARING FAILURE DURING VIBRATION TEST (CAR A7673). ANOTHER BEARING FAILED IN THE LO2 OUTBOARD F/D VALVE THAT

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WAS INSTALLED IN THE MPTA (CAR A9452), RESULTING IN BEARING COMPONENT DEBRIS IN THE MPS. THIS CONDITION WAS CORRECTED BY REDESIGN OF THE BEARING ASSEMBLY. IN ADDITION, FEEDLINE SCREENS WERE ADDED AT BOTH THE LH2 AND LO2 PREVALVE OUTLETS TO PREVENT DEBRIS OVER 1000 MICRONS FROM ENTERING THE ENGINE INLETS.

THE VALVE FAILED TO CYCLE PROPERLY DURING DELTA QUALIFICATION TESTING DUE TO LACK OF DRY FILM LUBRICANT IN THE DRIVE MECHANISM (CAR AC8794). THIS VALVE HAD BEEN REASSEMBLED FOR THE DELTA QUALIFICATION TESTING BUT THE MECHANISM WAS NOT REFURBISHED AT THAT TIME. THE POST TEST TEARDOWN INSPECTION AND CLEANING THAT WAS CONDUCTED AFTER THE ORIGINAL QUALIFICATION TEST PROGRAM REMOVED A PORTION OF THE DRY FILM LUBRICANT. THE MECHANISM WAS REFURBISHED AND SUCCESSFULLY COMPLETED ITS CERTIFICATION.

FIELD INSPECTION OF ALL ACTUATOR BOLTS (SAR J-1648) DISCLOSED A NUMBER OF BOLTS WITH LOW TORQUE VALUE. ALL ACTUATOR BOLTS WERE CHECKED, RETORQUED, AND VERIFIED BY A PROCEDURE DURING SWITCH MODIFICATION.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

(E) OPERATIONAL USE:

FLIGHT: FOR POST MECO DUMP OPERATIONS, THE CREW WILL OPEN THE LH2 RTLS DUMP VALVES (PV17,18) WHEN THE LH2 MANIFOLD PRESSURE EXCEEDS CAUTION AND WARNING LIMITS.

GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN SYSTEM.

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: STUART KOBATA	: /S/ STUART KOBATA
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: WILLIAM LANE	: /S/ WILLIAM LANE
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS